BELA Major Lesson 2

Electricity and Batteries

Aaron Curry

Audience: 8th grade

Timeframe: 4 class periods of 90 minutes.

Abstract: The purpose of this lesson is for the students to get some hands-on experience with circuits. They will do a wide variety of exercises to enhance their learning. They will have two days of hands-on activities and then two days building their own batteries from household materials. They will use multimeters to measure voltages and currents and even use their batteries to power up calculators. They will compete to see who can make the ‘best’ battery.

Learning Objectives: The students will learn about the basic principles of circuits. They will learn what a conductor and insulator is and what closed and open circuits are. They will learn what series circuits and parallel circuits are. They will then learn about voltage and current and how to measure each using a multimeter. They will learn how batteries work and how to boost voltage or current by placing batteries in series or parallel. They will learn how to make their own batteries using household materials and compete to try to make the best battery.

Sources:

http://sci-toys.com/scitoys/scitoys/echem/batteries/batteries.html
http://www.wikihow.com/Create-a-Battery-from-a-Lemon
http://www.kidzworld.com/article/4726-how-potato-batteries-work

Materials:

- Batteries (LR44, AA, D)
- pennies
- paper clips
- soda
- Vinegar
- Potatoes
- Alligator Clips
- limes
- Low-power calculators
- multimeters
- battery holders
- energy balls
- Rubber bands
- newspaper
- soda cans
- pencils
- Pens
**Day 1:** The first day the students will learn about basic circuits. They will learn that electricity is the flow of electrons. They will learn that some materials allow electrons to flow more easily than others. They will learn that good conductors allow electrons to flow very well while good insulators do not allow electrons to flow at all. They will learn that a closed circuit has a path for electrons to flow while an open circuit does not have a path. They will learn that batteries or power outlets provide the energy source of a circuit (electrons). They will also learn what series and parallel circuits are.

The instructor used a power point to teach these concepts. The power point is attached. The students had to fill out an in-class work sheet during the lecture that had to be handed in at the end of class. The in-class work sheet is attached.

**Activity:** The students will use energy balls to test different materials to see if they are a good conductor or a good insulator. They must draw a closed circuit for conductors and an open circuit for insulators. They must fill out the activity work sheet and hand it in at the end of the day with their in-class work sheet. The in-class activity sheet is attached.

**What you will need:**

Energy balls: However many groups of students you want.

Materials: pennies, soda cans, paper clips, pencils, pens, rubber bands, newspapers, t-shirts, any other items.

**The set up:**

Have one of each material on a tray to be passed out to each group.

Show the students how to test each material with the energy balls.

Pass out the trays and energy balls.

**Day 2:** The second day students will learn batteries, voltage, and current. They will learn that batteries produce a flow of electrons from a chemical reaction and so they are called an electrochemical cell.

They will learn that voltage is a measure of the amount of potential energy a battery has. A good analogy is the water analogy. A battery is like a water pump. The amount of work or energy a water pump can provide to the water, the stronger the pump is. This strength is like the voltage in a battery. The higher the voltage, the stronger the battery.

They will learn that current is a measure of the amount of electrons flowing in a circuit. Again, using the water analogy, water flowing through pipes produces a current of water. In circuits you have the same thing but it is electrons instead of water. A very wide pipe will allow much more water to flow than a very narrow pipe.
They will learn how to measure voltage and current using multimeters. They will learn that to measure voltage, you apply both ends of the multimeter across the two terminals. They will learn that to measure current, you must break the circuit and place the two ends of the multimeter in series with the circuit.

The instructor used a power point to teach these concepts. The power point is attached. The students had to fill out an in-class work sheet during the lecture that had to be handed in at the end of class. The in-class work sheet is attached.

**Activity:** The students will use multimeters to measure the voltage a battery produces and the voltage and current that is required to operate a low power calculator. They must fill out the activity worksheet and turn it in with the in-class work sheet at the end of the class.

**What you will need:**

Multimeters: However many groups of students you want.

Batteries: LR44, D, and AA. 1 each for however many groups of students you want.

Low-power calculators: 1 each for however many groups of students you want. These can be purchased for very cheap. Be sure to use scotch tape to tape the solar panel so that the calculators do not turn on without a battery. Unscrew the back battery panel and remove the LR44 batter(y)ies from the back of the calculator.

Alligator clips: 3 each for however many groups of students you want.

Battery holders: 1 each for however many groups of students you want.

AA batter(y)ies: 1(2) each for however many groups of students you want. NOTE: if you are using a 3V calculator, you will need 2. If you are using a 1.5V calculator, you will need 1.

**The set up:**

Have 1 of each battery (AA, D, and LR44) on trays for each student group.

Show the students how to measure the voltage by selecting voltage on the multimeter and touching the ends to the ends of batteries. Comment on the importance of the +/- terminals.

Hand out the multimeters and let the students start the first exercise on the work sheet.

Collect the batteries when the students are finished.

Have a low power calculator, 3 alligator clips, 1(2) AA battery, and a battery holder on trays for each student group.

Pass out the materials and have the students start the second exercise on the work sheet.
**Days 3-4:** The third and fourth days the students will get to build their own batteries using common household materials. They can then use these batteries to power the low-power calculators from the second day. They can also compete to see whose battery can produce the most voltage or who can make a battery that powers a calculator for the least money or whose battery can power the most calculators in parallel.

**Day 3:** The students will learn how a copper-acid-zinc battery works. They will learn that through a chemical reaction, electrons flow from the zinc terminal to the copper terminal if they are given a closed route. Thus, the copper is the + terminal and the zinc is the – terminal.

The students will learn how to make their own batteries out of household materials. For copper they can use pennies. For zinc they can use paper clips. For the acid they can use any acidic product found at home: acetic acid (vinegar), citric acid (fruit, Gatorade), or phosphoric acid (potatoes, soda).

The students will learn that placing battery cells in series will boost the voltage that the cell provides. They will learn that placing the penny and paper clip closer in each medium increases the amount of current that can flow. They will learn that placing more pennies and paper clips in each acidic medium will increase the current flow.

The students will have a design guide to follow to walk them through the design process. They should know that the engineering process requires many attempts and modifications to their original design. Cost of materials can be included to see who can create a battery at the least expense.

Students can use multimeters to test their voltage. Current should not be measured as it will drastically drain the battery.

**What you will need:**

A pack of red solo cups: If the students chose to use vinegar or soda for their batteries they will need a container to put it in.

Scissors: to cut the cups to make them smaller if desired.

Pennies: Lots of pennies for the + terminals.

Paper Clips: Lots of paper clips for the – terminals.

Soda, Vinegar, potatoes, Gatorade, lemons, limes, or any other acidic product.

Tape.

Alligator clips: many alligator clips will be needed. Probably about 20 for each group.

Multimeters
The set up:

Have all of the materials ready for each student group. It is a good idea to have a tray for them to work on incase anything is spilled.

Have the students attempt a design on paper before you hand out any materials. Verify their design on paper will work.

NOTES:

The picture below is of batteries made by the instructor. In order to achieve the needed 1.5V, the students will need to place at least two battery cells in series. This is because each cell produces approximately .7-.9 Volts.

Day 4: Continued battery design. Students can continue designing and altering their batteries. They can use the multimeters to measure voltage and test their battery on the low-power calculators.

What you will need and Set up:

Same as from day 3.
In Class Assignment 1:

Questions. Answer the following questions:

What is a load? Give an example.

What is a conductor? Give an example.

What is an insulator? Give an example.

What is a resistor? Give an example.

Identification. Identify the following three pictures with:

Closed circuit
Open Circuit
Short circuit

NOTE: One is both closed and short!

On the back of this page, draw an example of a circuit with 3 resistors (loads) in series.

On the back of this page, draw an example of a circuit with 3 resistors (loads) in parallel.
What is a conductor?

- A conductor is something that allows electricity to pass through.

What is an insulator?

- An insulator is something that blocks electricity.

<table>
<thead>
<tr>
<th>Materials</th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>penny</td>
<td>pencil mark on paper</td>
<td>newspaper</td>
</tr>
<tr>
<td>soda can</td>
<td>pen mark on paper</td>
<td>t-shirt</td>
</tr>
<tr>
<td>paperclip</td>
<td>rubber band</td>
<td>try any 2 other items</td>
</tr>
</tbody>
</table>

**Conductors**

Hypothesis:

Test:

**Insulators**

Draw below the type of circuit a conductor and an insulator makes. (open or closed)

Conductor Circuit

Insulator Circuit
In Class Assignment 2:

Questions. Answer the following questions:

What is an electrochemical cell? Give an example.

What is voltage? According to the water analogy, what is voltage associated with?

What is current? According to the water analogy, what is current associated with?

Identification.

Draw how you would measure the voltage across the resistor:

![Voltage Measurement Diagram]

Draw how you would measure the current through the resistor (load):

NOTE: You may need to alter the circuit drawing.

![Current Measurement Diagram]

On the back of this sheet, draw how you would produce 4.5V with only 1.5V batteries.

On the back of this sheet, draw how you would produce .4mA with batteries that can produce .1mA.
In-Class Activity 2:

Measuring Voltage and Current

**Station 1: Battery Voltage Measurement**

Measure the voltage of a LR44 battery. What is its voltage potential?

Measure the voltage of a AA battery. What is its voltage potential?

Measure the voltage of a D battery. What is its voltage potential?

Why would we need 3 different types of batteries if they all have the same voltage potential?
Station 2: *Calculator Voltage and Current measurement*

Add one AA battery to the battery holder. Use one alligator clip to connect the + side of the battery holder to the + side of the calculator. Use another alligator clip to connect the – side of the battery holder to the – side of the calculator. Does the calculator work?

Measure the voltage the battery is producing to the calculator. What is the voltage potential?

Draw a picture of your circuit with the multimeter.

Now, break the circuit and put the multimeter in series with the battery cell and the calculator. You can do this by removing the alligator clip connecting to the + terminal of the calculator. Connect this end to the red end of the multimeter instead. Now use the third alligator clip to connect the black end of the multimeter to the + terminal of the calculator.

Measure the current the battery is producing to the calculator. What is the current?

Draw a picture of your circuit with the multimeter.
Engineer Your Own Battery:
Introduction

A battery is an electrochemical cell. It converts STORED chemical energy into USABLE electrical energy. A battery can be made with common household things. All you need is copper (pennies are coated with copper), zinc (any shiny metal such as paperclips) and an acid (fruit, soda, vinegar, potatoes).

Assignment

You will be engineering your own battery with the following considerations:

1) Your battery should be able to power a low-power calculator.
2) You should try to get a calculator working at the lowest cost.
3) Your battery should produce the most voltage.
4) Your battery can power the most calculators at once.

List and cost of materials

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red SOLO cup</td>
<td>$x</td>
</tr>
<tr>
<td>Lime</td>
<td>$x</td>
</tr>
<tr>
<td>Potatoe</td>
<td>$x</td>
</tr>
<tr>
<td>Penny</td>
<td>$x</td>
</tr>
<tr>
<td>Paper Clip</td>
<td>$x</td>
</tr>
<tr>
<td>Soda</td>
<td>$x</td>
</tr>
<tr>
<td>Vinegar</td>
<td>$x</td>
</tr>
<tr>
<td>Alligator Clips (20 per group)</td>
<td>$x</td>
</tr>
<tr>
<td>Tape</td>
<td>$x</td>
</tr>
</tbody>
</table>

Power Levels of the Calculator

As you should have discovered from the last day of class, a low-power calculator uses about 1.5V and consumes about .04-.08mA. Your battery thus needs to produce at least 1.5V.
**STEP 1) Design**

Design a battery cell with the following considerations:

1: It must have at least 1 penny and 1 paper clip.

2: It must have 1 acid: soda, vinegar, potato, lime, Gatorade.

3: Your group has a limited number of alligator clips.

You should make at least 3 different designs you want to try out. Draw your three designs below.

**NOTE:** How would you increase your voltage output from your three designs? Write how you would accomplish this in the following space.
STEP 2) Turn your design in to the teacher and get approval/feedback.

STEP 3) Decide on a design you want to build.

STEP 4) Request the materials from the teacher if you have approval.

STEP 5) Test your battery.

STEP 6) Alter your design to make improvements. Repeat steps 3-6.

Remember, the engineering process is not a simple one. Things hardly ever work on the first try. It takes multiple tries and tests in order to get things to work the way you want them to! Build, test, and rebuild!
Electricity, Circuits, and conductors.

Aaron Curry
At the end of today you will know what an electric circuit is made of and its different types.

Components:
- Source
- Load
- Conductor
- Insulator

Types:
- Closed circuit
- Open circuit
- Series circuit
- Parallel circuit
Electricity is the flow of electrons.
Circuit: “A circular line or route”

Which way do electrons flow?

The **source** is the device that provides the energy for the circuit.
What is a load?
**Load**: the device that is connected to the power source.
A "Closed" circuit

Load
A closed and open circuit

“Closed”

“Open”

Load

Load
Conductors allow electrons to flow through them.

Insulators do not allow electricity to flow through them.
Conductors and insulators

Good Conductors
- Metals
  - Copper

Good Insulators
- Nonmetals
  - Sulfur
Usually our load is in between a good conductor and an insulator.

A **Resistor** is a load that is anywhere in between a good conductor and an insulator.
What if our load is an insulator?

Open Circuit!
What if our load is a good conductor?

SHORT Circuit!
Short Circuit!
The Electric Fence Video
What Is Going On?
Closed Circuit!
Series Circuits

Loads are one after another in the circuit.
If you remove a load... it breaks the circuit!
Parallel Circuits

Loads are side-by-side in the circuit. If you remove a load... it DOES NOT break the circuit.
Series Versus Parallel

Series

Parallel

Things are in series with one another.

Things are in parallel with one another.
What are we doing today?
Batteries, Volts, and Current.

Aaron Curry
At the end of today you will know what a battery is made of, what its properties and how to measure them.

Made of: Copper
Zinc
Acid

Properties: Voltage
Current
Battery Life

Measure: Voltage measurement
Current measurement
What do you use batteries for?
The Tesla

http://www.youtube.com/watch?v=En9vejQ-Xzw
A battery is a device that stores energy.

Chemical energy is stored.

Electrical energy is produced.

Electrochemical Cell.
Let's Look Inside:

\[ 
\text{Cu} + 3\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2
\]

\[ 
\text{Zn} + \text{PO}_4^{3-} + 2\text{H}_2\text{O} \rightarrow \text{Zn}^{2+} + 3\text{H}^+ + 2\text{e}^- 
\]
Properties of Batteries

Voltage (V)

Voltage: a measure of the amount of POTENTIAL ENERGY a battery can produce.
The water analogy:

A battery is like a water pump.

Voltage is like the height a pump can pump water.
Properties of Batteries

**Current**: a measure of the rate at which electrons flow between the battery’s terminals.
The water analogy:

A battery is like a water pump.

Current is like the rate of water flowing in a water pipe.
Life Span (mAh)

**Life Span**: a measure of the amount of total energy stored in the battery.
The water analogy:

A battery is like a water pump. Life span is like how long the water supply will last at a given current.
How Do We Measure?

Multimeter
Measure the Voltage
NOTE: In order to measure current, we need to have a CLOSED LOOP.
Example: Voltage Measurement
Example: Current Measurement
Boosting Voltage with batteries

What if you needed 3V but only had 1.5V batteries?

Put them in SERIES!
What if you needed to produce .2mA but only had batteries that could produce .1mA?

Put them in PARALLEL!
What we will do today
Battery Design Challenge

Aaron Curry
You know how to make a battery.
You know what the design challenge is.
You know techniques to increase your batteries voltage output.
You know techniques to increase your batteries current output.
Did you know

You can make your own batteries with common household items!
All you need is:

- Something made of copper
- Any galvanized metal
- Anything that has acid in it
Common items that have acid:

Citrus fruits and Gatorade contain CITRIC ACID

Potatoes and Soda contain PHOSPHOHIRIC ACID

Vinegar contains ACETIC ACID
Inside the battery

Cu + Zn

\[ \begin{align*}
3H^+ + Zn^{2+} & \rightarrow 2H_2 + PO_4^{3-}
\end{align*} \]
Example
Your objective:

Design a battery that can power:

Design a battery with the MOST voltage-current product.

\[ V \times I \]
How can we boost the voltage potential?

What if you needed 3V but only had 1.5V batteries?

Put them in SERIES!
Examples

1V

2V

1V
How can we boost the current output?

1. Distance of electrodes:

- Lower current
- Higher current
What if you needed to produce .2mA but only had batteries that could produce .1mA?

Put them in PARALLEL!
How can we boost the current output?

2. Put multiple paths in the cell:

- Red Cup
- Bottom
- Copper Penny
- Zinc Paperclip
- Acid solution
3. Put multiple cells in parallel:
At your table groups you will be building your own battery

Your battery must power a calculator

Your battery should power a mouse

Your battery may be able to power the battle bots

BONUS: group with the battery with the most voltage-current product output.

\[ V \times I \]